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BIBLIOGRAPHY

1. Adrian, E. D., and Bronk, D. W. The discharge of impulses in motor nerve fibers. *J. Physiol.*, 1928, *66:* 81–101.
2. Adrian, E. D., and Zotterman Y. The impulses produced by sensory nerve endings. Part 2. The response of a single end organ. *J. Physiol.*, 1926, *61:* 151–171.
3. Bronk, D. W., and Ferguson, L. K. The nervous control of intercostal respiration. *Amer. J. Physiol.*, 1935, *110:* 700–707.
4. Gesell, R., Atkinson, A. K., and Brown, R. C. The gradation of the intensity of inspiratory contraction. *Amer. J. Physiol.*, 1941, *131:* 659–673.
5. Gesell, R., Magee, C., and Bricker, J. Activity patterns of the respiratory neurons and muscles. *Amer. J. Physiol.*, 1940, *128:* 615–628.
6. Lloyd, D. P. C. The interaction of antidromic and orthodromic volleys in a segmental spinal motor nucleus. *J. Neurophysiol.*, 1943, *6:* 143–151.
7. Lorente de Nó, R. Limits of variation of the synaptic delay of motoneurons. *J. Neurophysiol.*, 1938, *1:* 187–194.
8. Lorente de Nó, R. Analysis of the activity of the chains of internuncial neurons. *J. Neurophysiol.*, 1938, *1:* 207–244.
9. Pitts, R. F. The differentiation of respiratory centers. *Amer. J. Physiol.*, 1941, *134:* 192–201.
10. Pitts, R. F. Excitation and inhibition of phrenic motor neurons. *J. Neurophysiol.*, 1942, *5:* 75–88.
11. Pitts, R. F. The functions of components of the respiratory complex. *J. Neurophysiol.*, 1942, *5:* 403–413.
12. Pitts, R. F., Magoun, H. W., and Ranson, S. W. Interrelations of the respiratory centers in the cat. *Amer. J. Physiol.*, 1939, *126:* 689–707.
13. Pitts, R. F., Magoun, H. W., and Ranson, S. W. The origin of respiratory rhythmicity. *Amer. J. Physiol.*, 1939, *127:* 654–670.
14. Ranson, S. W., and Hinsey, J. C. Reflexes in the hind limbs of cats after transection of the spinal cord at various levels. *Amer. J. Physiol.*, 1930, *94:* 471–495.
15. Renshaw, B. Activity in the simplest spinal reflex pathways. *J. Neurophysiol.*, 1940, *3:* 373–387.

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